Standard Method of Test for

Theoretical Maximum Specific Gravity and Density of Hot-Mix Asphalt Paving Mixtures

AASHTO Designation: T 209-05

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Method of Test for

Theoretical Maximum Specific Gravity and Density of Hot-Mix Asphalt Paving Mixtures

AASHTO Designation: T 209-05

1. SCOPE

1.1. This test method covers the determination of the theoretical maximum specific gravity and density of uncompacted hot-mix asphalt paving mixtures at 25°C (77°F).

Note 1—The precision of the method is best when the procedure is run on samples that contain aggregates that are completely coated. In order to assure complete coating it is desirable to run the method on samples that are close to the optimum asphalt content.

1.2. The values stated in SI units are to be regarded as the standard.

1.3. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use*.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 132, Terms Relating to Density and Specific Gravity of Solids, Liquids, and Gases
- R 10, Definition of Terms for Specifications and Procedures
- T 168, Sampling Bituminous Paving Mixtures

2.2. *ASTM Standards*:

- D 4311, Practice for Determining Asphalt Volume Correction to a Base Temperature
- E 1, Specification for ASTM Thermometers

3. TERMINOLOGY

3.1. The terms *specific gravity* and *density* used in this test method are in accordance with M 132.

3.2. *Definitions*:

3.2.1. *density, as determined by this test method*—the mass of a cubic meter of the material at 25°C in SI units, or the mass of a cubic foot of the material at 25°C in inch–pound units.

3.2.2. *residual pressure, as employed by this test method*—the pressure in a vacuum vessel when vacuum is applied.

3.2.3. *specific gravity, as determined by this test method*—the ratio of a given mass of material at 25°C (77°F) to the mass of an equal volume of water at the same temperature.

4. SUMMARY OF TEST METHOD

4.1. A weighed sample of oven-dry paving mixture in the loose condition is placed in a tared vacuum vessel. Sufficient water at a temperature of 25 ± 0.5°C (77 + 0.9°F) is added to completely submerge the sample. Vacuum is applied for 15 ± 2 min to gradually reduce the residual pressure in the vacuum vessel to 3.7 ± 0.3 kPa (27.5 + 2.5 mm Hg). At the end of the vacuum period, the vacuum is gradually released. The volume of the sample of paving mixture is obtained either by (Section 9.5.1) immersing the vacuum container with sample into a water bath and weighing or by (Section 9.5.2) filling the vacuum container level full of water and weighing in air. At the time of weighing, the temperature is measured as well as the mass. From the mass and volume measurements, the specific gravity or density at 25°C (77°F) is calculated. If the temperature employed is different from 25°C (77°F), an appropriate correction is applied.

Comment [J1]: This is not indicated on the ballot. But, the ± 4 seems like an error. The 23rd and 24th Editions says ± 4 as well.

5. SIGNIFICANCE AND USE

5.1. The theoretical maximum specific gravities and densities of hot-mix asphalt paving mixtures are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and bituminous materials.

5.1.1. They are used to calculate values for percent air voids in compacted hot-mix asphalt paving mixtures.

5.1.2. They provide target values for the compaction of paving mixtures.

5.1.3. They are essential when calculating the amount of bitumen absorbed by the internal porosity of the individual aggregate particles in a hot-mix asphalt paving mixture.

6. APPARATUS

6.1. *Vacuum Container*:

6.1.1. The vacuum containers described must be capable of withstanding the full vacuum applied, and each must be equipped with the fittings and other accessories required by the test procedure being employed. The opening in the container leading to the vacuum pump shall be covered by a piece of 75-µm (No. 200) wire mesh to minimize the loss of fine material.

6.1.2. The vacuum container size should be between 2000 and 10,000-mL and depends on the minimum sample size requirements given in Section 7.2. Avoid using a small sample in a large container.

6.1.3. *Vacuum Bowl*—Either a metal or plastic bowl with a diameter of approximately 180 to 260 mm (7.1 to 10.2 in.) and a bowl height of at least 160 mm (6.3 in.) shall be equipped with a transparent cover fitted with a rubber gasket and a connection for the vacuum line.

Comment [J2]: Where are the original subsections? Is the Original document from the 23rd Edition?

6.1.4. *Vacuum Flask for Weighing in Air Only*—A thick-walled volumetric glass flask and a rubber stopper with a connection for the vacuum line.

6.1.5. *Pycnometer for Weighing in Air Only*—A glass, metal or plastic pycnometer.

6.2. *Balance*—with ample capacity, and with sufficient sensitivity to enable the specific gravity of samples of uncompacted paving mixtures to be calculated to at least four significant figures: that is, to at least three decimal places. For the bowl method , the balance shall be equipped with a suitable apparatus and holder to permit weighing the sample while suspended below the balance. The apparatus must have the same sensitivity, capacity and accuracy as the top pan.

6.2.1. Wire suspending the holder should be the smallest practical size to minimize any possible effects of a variable immersed length.

6.3. *Vacuum pump or water aspirator*—capable of evacuating air from the vacuum container to a residual pressure of 4.0 kPa (30mm Hg).

6.3.1. When a vacuum pump is used, a suitable trap of one or more 1000-mL filter flasks, or equivalent, shall be installed between the vacuum vessel and vacuum source to reduce the amount of water vapor entering the vacuum pump.

6.4. *Residual Pressure Manometer*[1]—or vacuum gage traceable to NIST (mandatory) to be connected directly to the vacuum vessel and to be capable of measuring residual pressure down to 4.0 kPa (30mm of Hg) or less (preferably to zero). It is to be connected at the end of the vacuum line using an appropriate tube and either a "T" connector on the top of the vessel or by using a separate opening (from the vacuum line) in the top of the vessel to attach the hose. To avoid damage, the manometer itself is not to be situated on top of the vessel but adjacent to it.

Note 2—A residual pressure of 4.0 kPa (30 mm Hg) absolute pressure is approximately equivalent to 97 kPa (730 mm Hg) reading on vacuum gage at sea level.

Note 3—Residual pressure in the vacuum vessel, measured in millimeters of mercury, is the difference in the height of mercury in the Torricellian vacuum leg of the manometer and the height of mercury in the other leg of the manometer that is attached to the vacuum vessel.

6.5. *Manometer or Vacuum Gage*—suitable for measuring the vacuum being applied at the source of the vacuum. This device can be connected directly to the vacuum source or be in the vacuum line close to the source. This is required to check the reading given by the residual pressure manometer attached directly to the vacuum vessel.

Note 4—The Torricellian vacuum leg of the manometer occasionally acquires one or more bubbles of air that introduce error into the residual pressure reading. By the addition of the vacuum gage this error can often be quickly detected by the differences between two vacuum measurements.

6.6. *Thermometers*—calibrated liquid-in-glass thermometers of suitable range with subdivisions and maximum scale error of 0.5°C (0.9°F), or any other thermometric device of equal accuracy, precision and sensitivity shall be used. Thermometers shall conform to the requirements of ASTM E 1.

6.7. *Water Bath*:

6.7.1. For vacuum bowls, a water bath that can be maintained at a constant temperature between 20 and 30°C (68 and 86°F) is required. (See Appendix.)

6.7.2. When using the weighing-in-water technique, the water bath must be suitable for immersion of the suspended container with its deaerated sample.

6.8. *Bleeder Valve*—attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum vessel.

6.9. *Protective Gloves*—used when handling glass equipment under vacuum.

Note 5—An example of a correct arrangement of the testing equipment is shown in Figure 1. In the figure, the purpose of the train of small filter flasks is to trap water vapor from the vacuum vessel that otherwise would enter the oil in the vacuum pump and decrease the pump's ability to provide high vacuum.

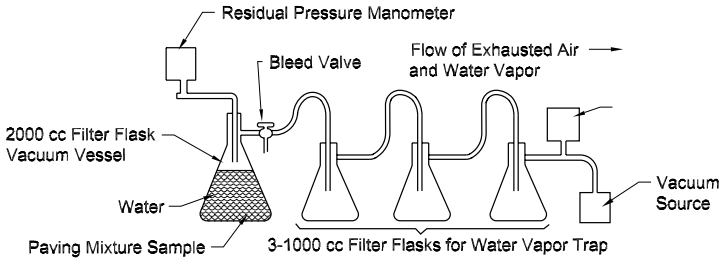

Figure 1—An example of the correct arrangement of testing apparatus

7. SAMPLING

7.1. Obtain the sample in accordance with T 168.

7.2. The size of the sample shall conform to the following requirements. Samples larger than the capacity of the container may be tested a portion at a time.

Nominal Maximum size *	Minimum Sample Size, g
50.0 (2)	6000
37.5 ($1^1/_2$)	4000
25.0 (1)	2500
19.0 ($^3/_4$)	2000
12.5 ($^1/_2$)	1500
9.5 ($^3/_8$)	1000
4.75 (No. 4)	500

*Nominal Maximum Aggregate Size- one sieve size larger than the first sieve to retain more than 10 percent.

8. CALIBRATION OF FLASKS, BOWLS, AND PYCNOMETERS

8.1. For the weighing-in-water method (Section 9.5.1), the mass of the vacuum bowls shall be calibrated for temperature correction by determining the mass of each when immersed in water over the range of water bath temperatures likely to be encountered in service (Figure 2).

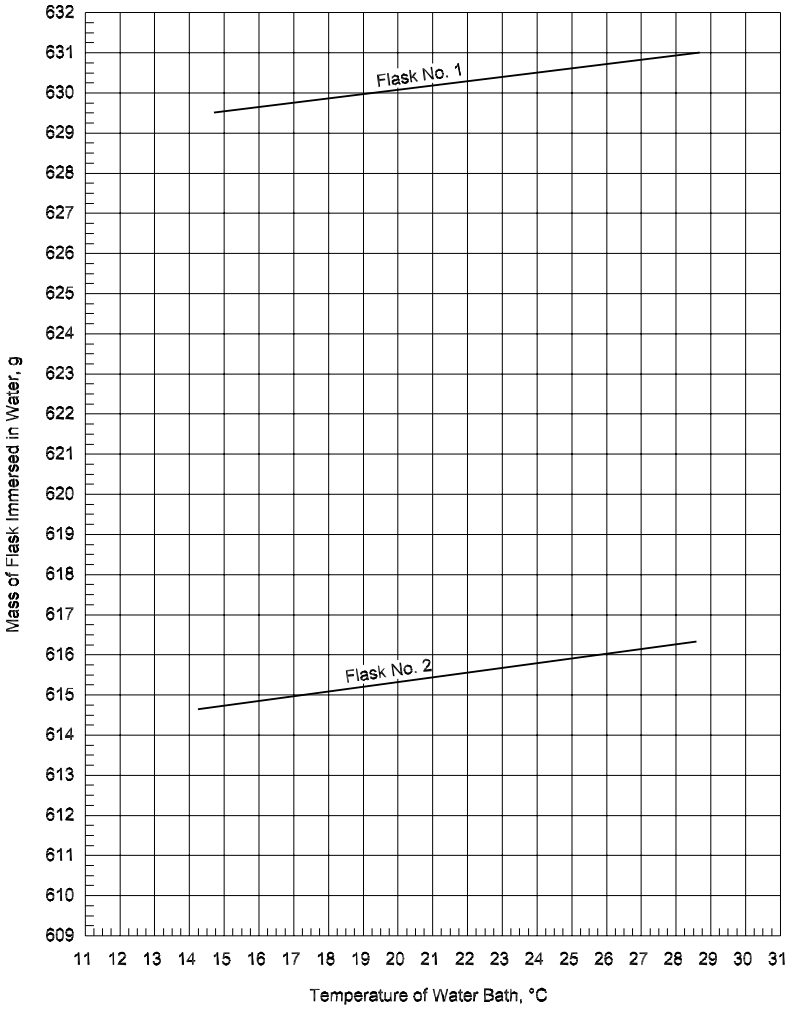

Figure 2—Example Calibration Curve for Volumetric Flask (B)

8.2. For the weighing-in-air method (Section 9.5.2), calibrate the volumetric flasks or pycnometers by determining the mass of the container when filled with water over the range of water temperatures likely to be encountered in service (Figure 3). When calibrated at 25 ± 0.5°C (77 ± 0.9°F) designate this mass as *D*. Accurate filling may be ensured by the use of a glass cover plate.

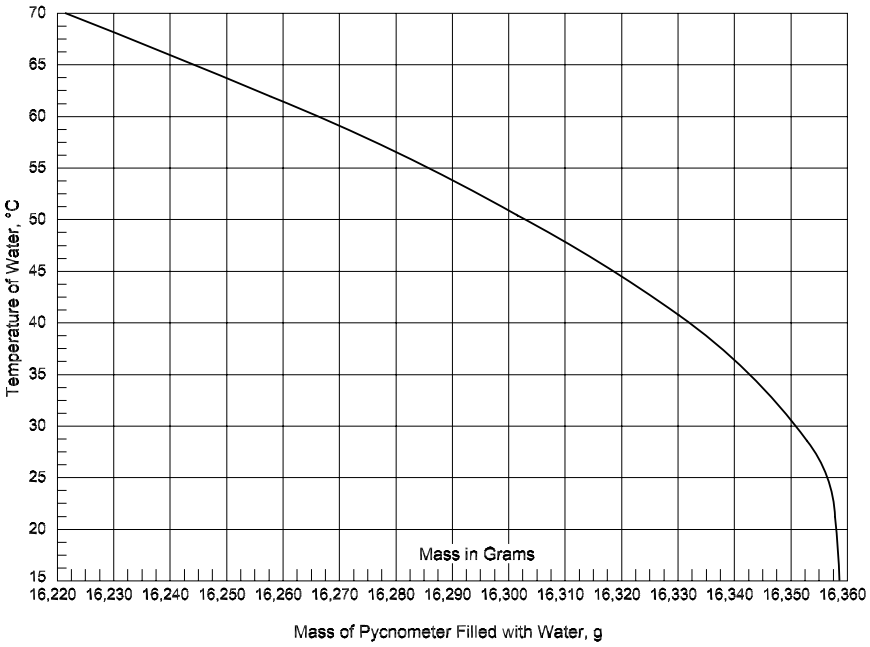

Figure 3—Example Calibration Curve for Pycnometer (D)

8.3. Calibrate the large-size plastic pycnometer by accurately determining the mass of water required to fill it over a range of temperature from about 20 to 65°C (70 to 150°F), and construct a calibration curve of mass versus temperature as shown in Figure 3. Care should be taken to follow exactly the same procedure in calibration as in conducting a test.

8.3.1. The following filling procedure may be used for the model with a latched lid and vented stopper. The domed lid is latched in place and the pycnometer nearly filled with water. Leave about 50 mm (2 in.) empty. The release of air bubbles may be facilitated by applying vacuum and by jarring (dropping first one side then the other of the pycnometer about 10 mm ($^1/_2$ in.) on the bench surface). This vacuum application and bubble release procedure should take about 10 min. so that the temperature equilibrium between the shell and the water approximates that attained when running a test. The final amount of water is then gently poured in until the level is about halfway up into the neck. Any air bubbles caught against the dome that cannot be released by jarring or by swirling the water may be "pricked" or pushed to the surface with a bent wire. Insert the vented stopper using only enough force to just seat the stopper and immediately wipe the excess water off the top.

8.3.2. For the models with quick disconnect vacuum line and unlatched lid, the filling procedure is as follows. With the inlet valve closed, apply vacuum of about 30 kPa (10 in.) of Hg. Open the inlet valve slowly letting water in until the level reaches 25 mm (1 in.) below the top of the dome and close the valve. Continue applying vacuum and release the bubbles by jarring and rapping the vessel with a rubber mallet. Slowly open the inlet valve and allow more water in until the water overflows into the aspirator (vacuum) line and then close the valve. This vacuum application and bubble release procedure should take about 10 minutes so that the temperature equilibrium between the shell and the water approximates that attained when running a test. Disconnect by pulling out at the quick-disconnect joint below the gage.

8.3.3. The outside of the pycnometer is then wiped dry, the full pycnometer weighed, and the temperature of the water measured.

Note 6—The shape of the calibration curve is a function of two opposing factors that can be rationally defined. As the temperature is increased, the container itself expands (adding mass—"pycnometer" line in Figure 4) and the density of the contained water decreases (resulting in loss of mass—"Water" line in Figure 4). These relationships are shown in Figure 4 for a typical large-size pycnometer. The "Water" curve may be constructed by multiplying the volume at 25°C (77°F) by the difference in density of water at 25°C (77°F), which is 0.9970, and the density of water at the calibration temperature.

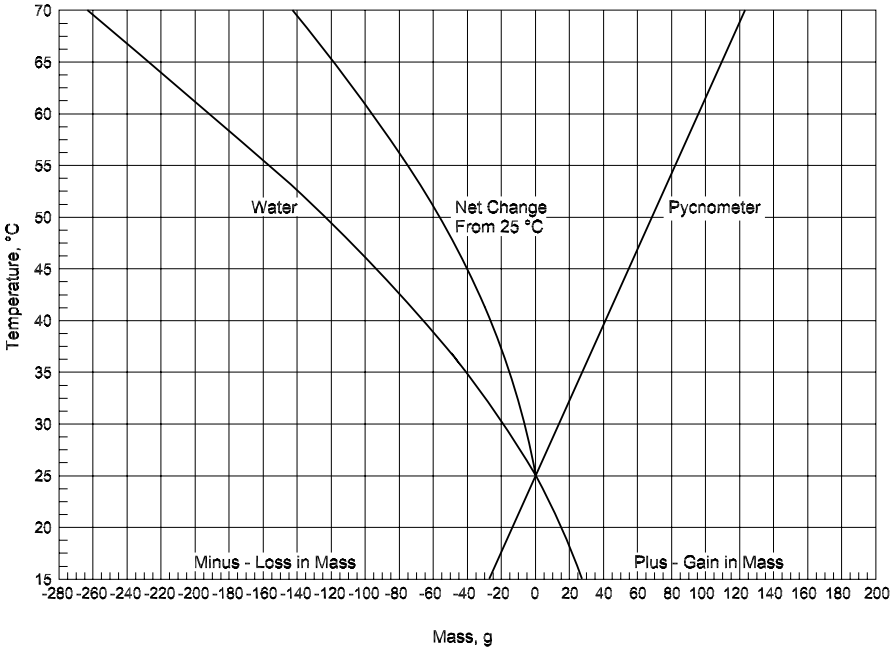

Figure 4—Effect of Change in Density of Water and Volume of Pycnometer (F) with Change in Temperature

$$\text{Difference Due to Water Expansion} = V_{25}(0.9970 - dw)$$

$$\text{Since } V_{25} = W_{25} / 0.9970 \qquad (1)$$

$$V_{25}(0.9970 - dw) \text{ Reduces to } W_{25}\left(1 - \frac{dw}{0.9970}\right)$$

where:

V_{25} = volume of water to fill container at 25°C (77°F), cm^3;
W_{25} = mass of water to fill container at 25°C (77°F), g; and
dw = density of water at calibration temperature, Mg/m^3.

The rate of change in capacity of the container due to thermal expansion of the pycnometer itself is essentially constant over the temperature range from 20 to 65°C (70 to 150°F). Thus, the "Pycnometer" line in Figure 4 can be drawn through the 0 at 25°C (77°F) point knowing only the slope of the straight line relationship. The slope can be established by averaging at least five calibration weighings at some elevated temperature, adding the loss due to water expansion and subtracting the mass at 25°C (77°F), W_{25}, to give the gain in capacity due to expansion of the container. The difference in mass divided by the difference in temperature is the slope of the "Pycnometer" line. For a polycarbonate pycnometer of about 13,500-mL capacity, the slope thus established was 2.75 g/°C (1.53 g/°F). This is believed to be typical and reasonably constant.

The bending of the calibration curve (Figure 3) due to these offsetting thermal factors thus minimizes experimental error due to temperature effects in the normal working range, 25°C (77°F), for both the volumetric flask and the pycnometer containers. Defining the calibration curve makes it possible to correct for temperature, rather than "bring-to-temperature," thereby eliminating the cost of a water bath and making it feasible to improve accuracy by testing larger samples and to materially reduce testing time.

8.4. While calibration of the flask or either pycnometer need be done only once, the calibration should be checked occasionally, particularly at 25°C (77°F). The equipment must be kept clean and free from any accumulation that would change the mass if the volume calibration is to remain constant. Care should be taken to use only neutral solvents, especially with plastic containers; glass vessels should not be subjected to high vacuum if they are scratched or damaged.

9. PROCEDURE

9.1. Separate the particles of the sample of paving mixture by hand, taking care to avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than 6.3 mm ($^1/_4$ in.). If a sample of paving mixture is not sufficiently soft to be separated manually, place it in a flat pan, and warm it in an oven until it can be separated as described.

9.2. Samples prepared in a laboratory shall be cured and dried in an oven at 135 ± 5°C (275 + 9°F) for a minimum of two hours, or as appropriate to match the mix design procedure being used. Longer drying time may be necessary for the sample to achieve a constant mass (mass repeats within 0.1 percent). Paving mixtures which have not been prepared in a laboratory with oven-dried aggregates shall be dried to a constant mass at a temperature of 105 ± 5°C (221+ 9°F). This drying and curing shall be combined with any warming described in Section 9.1.

Note 7—The minimum two-hour time in the oven is specified as cure time for laboratory-prepared specimens. The curing at the specified temperature is especially important when absorptive aggregates are used. This will ensure the computation of realistic values for the amount of asphalt absorbed by the aggregate and void properties of the mix. Plant-produced materials should not be cured since absorption takes place during production.

9.3. Cool the sample to room temperature and place it in a tared and calibrated flask, bowl, or pycnometer. The sample is to be placed directly into a vacuum container. A container within a container is not to be used. Weigh and designate the net mass of the sample as *A*. Add sufficient water at a temperature of approximately 25°C (77°F) to cover the sample completely.

9.4. Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads 3.7 ± 0.3 kPa (27.5 + 2.5 mm Hg). Maintain this residual pressure for 15 ± 2 minutes. Agitate the container and contents during the vacuum period either continuously by a mechanical device, or manually by vigorous shaking at intervals of about two minutes. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum.

Note 8—The release of entrapped air may be facilitated by the addition of a suitable wetting agent such as Aerosol OT in concentration of 0.001 percent or 0.2 grams in 20 L of water. This solution is then diluted by about 20:1 to make a wetting agent of which 5 to 10 mL may be added to the apparatus.

9.5. At the end of the vacuum period, release the vacuum by increasing the pressure at a rate not to exceed 8 kPa per second and proceed with one of the following determinations:

9.5.1. *Weighing in Water*—Suspend the container and contents in the water bath and determine the mass after 10 ± 1 min immersion. Measure the water bath temperature, and if different from 25 ± 1°C (77 ± 1.8°F), correct the mass to 25°C using the calibration temperature adjustment developed in Section 8.1. Designate the mass of the sample in water at 25°C as *C*.

Note 9—Instead of using a chart like Figure 2 to establish the mass correction for the temperature of the vacuum vessel submerged by itself in the water bath, this correction can be easily established by rapidly and completely emptying the vacuum container immediately following the final weighing, and then without delay, weighing the vessel by itself when totally submerged in the water bath.

9.5.2. *Weighing in Air*—Fill the flask or any one of the pycnometers with water and adjust the contents to a temperature of 25 ± 1°C (77 ± 1.8°F). Determine the mass of the container and contents, completely filled, in accordance with Section 8.2 within 10 ± 1 min after completing Section 9.4. Designate this mass as *E*.

Note 10—See Appendix for correcting the theoretical maximum specific gravity when measurements are made at temperatures other than 25°C (77°F).

10. CALCULATION

10.1. Calculate the theoretical maximum specific gravity of the sample at 25°C (77°F)as follows:

10.1.1. *Weighing in Water*:

$$\text{Theoretical Maximum Specific Gravity} = \frac{A}{A - C} \qquad (2)$$

where:

A = mass of oven-dry sample in air, g; and
C = mass of water displaced by sample at 25°C (77°F), g.

10.1.2. *Weighing in Air*:

$$\text{Theoretical Maximum Specific Gravity} = \frac{A}{A + D - E} \qquad (3)$$

where:

A = mass of oven-dry sample in air, g;
D = mass of container filled with water at 25°C (77°F), g; and
E = mass of container filled with sample and water at 25°C (77°F), g.

10.1.3. *Large-Size Plastic Pycnometer Determinations*:

10.1.3.1. If the test temperature is within +1.7 or –2.8°C (+3 or –5°F) of 25°C (77°F), that is, between 22.2 and 26.7°C (72 and 80°F), Equation 3 may be used to calculate specific gravity within 0.001 points or less error due to thermal effects.

10.1.3.2. If the test temperature differs significantly from 25°C (77°F), correct for thermal effects as follows:

$$\text{Specific Gravity} = \frac{A}{(A+F)-(G+H)} \times \frac{dw}{0.9970} \qquad (4)$$

where:

A = mass of dry sample in air, g;
F = mass of pycnometer filled with water at test temperature (Figure 3), g;
G = mass of pycnometer filled with water and sample at test temperature, g;
H = correction for thermal expansion of bitumen (Figure 5), g;
dw = density of water at test temperature, Curve D in Figure 6, Mg/m^3; and
0.9970 = density of water at 25°C (77°F), Mg/m^3.

The ratio (dw/0.9970) is Curve R in Figure 6.

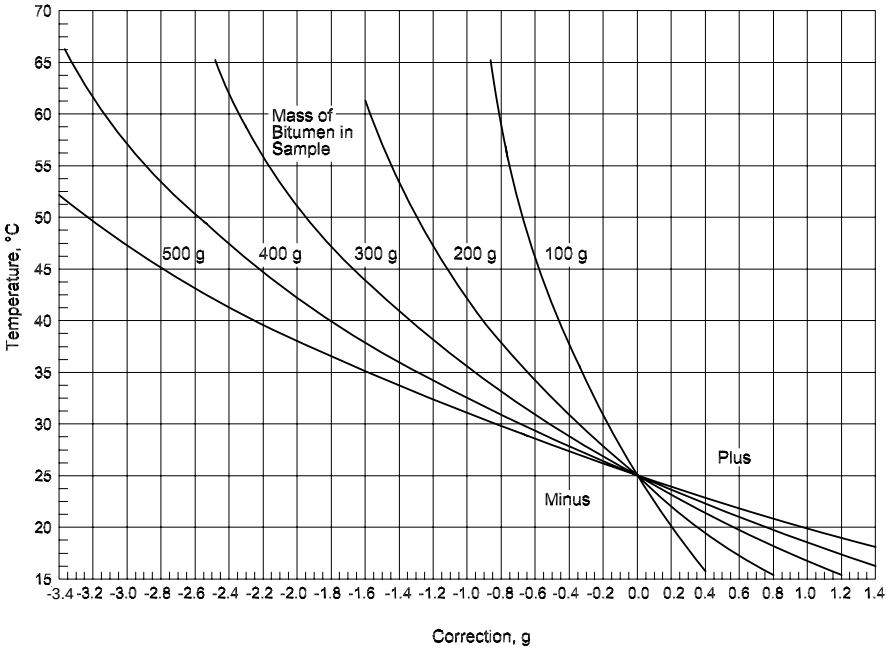

Figure 5—Correction Curves for Expansion of Bitumen, *H*, in Equation 4

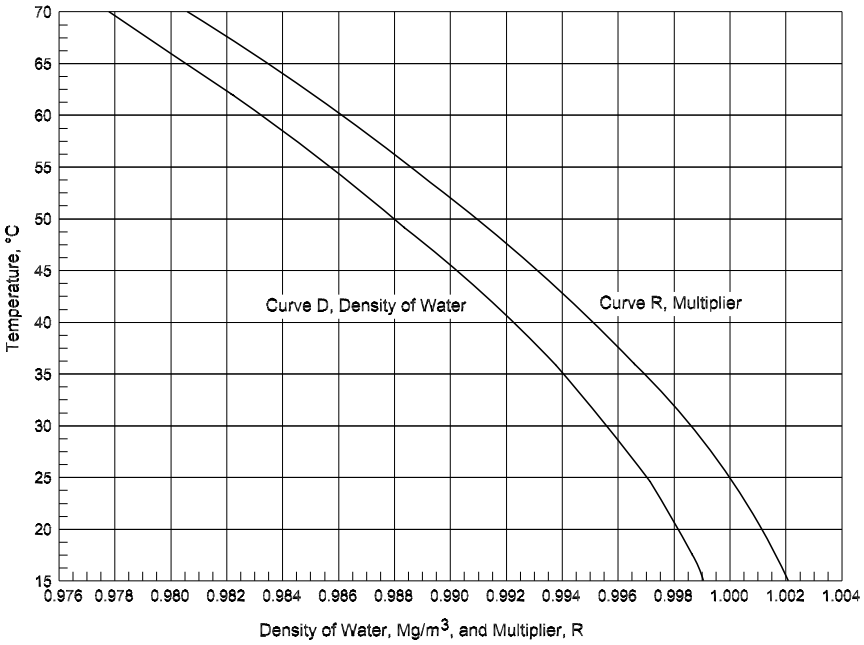

Figure 6—Curves D and R for Equation 4

Note 11—This general procedure for correcting for thermal effects should also be applicable to corresponding measurements made with other suitable containers.

10.1.4. When it is necessary to test a sample a portion at a time, the differences between the maximum specific gravities for each portion should be within the precision statements listed in Section 13. If the values are within the precision statements, the specific gravities for each portion shall be averaged. If the values are outside the precision statements, the test shall be run again.

Note 12—When samples are run a portion at a time, differences between the maximum specific gravities for each portion may be larger than those listed in Section 13. If there is a concern over the result of the test, another test should be run and the results of the two tests should be within the limits in Section 13.

10.2. *Theoretical maximum density at 25°C (77°F)*:

10.2.1. Calculate the corresponding theoretical maximum density at 25°C (77°F) as follows:

Theoretical maximum density at 25°C (77°F) = theoretical maximum specific gravity × 997.1 kg/m^3 in SI units, or

Theoretical maximum density at 25°C (77°F) = theoretical maximum specific gravity × 62.245 lb/ft^3 in inch–pound units.

where:

The specific gravity of water at 25°C (77°F) = 997.1 in SI units or = 62.245 in inch–pound units.

11. SUPPLEMENTAL PROCEDURE FOR MIXTURES CONTAINING POROUS AGGREGATE

Note 13—Experiments indicate that the supplemental procedure has an insignificant effect on the test results if the mixture contains individual aggregate with a water absorption below 1.5 percent.

11.1. If the pores of the aggregates are not thoroughly sealed by a bituminous film, they may become saturated with water during the evacuation procedure. To determine if this has occurred, proceed as follows after completing the procedure in accordance with Section 9.5.1 or 9.5.2. Drain water from the sample. To prevent loss of fine particles, decant water through a towel held over the top of the container. Break several large pieces of aggregate and examine broken surfaces for wetness.

11.2. If the aggregate has absorbed water, spread the sample before an electric fan to remove surface moisture. Weigh at 15-minute intervals, and when the loss in mass is less than 0.05 percent for this interval, the sample may be considered to be surface dry. This procedure requires about two hours and shall be accompanied by intermittent stirring of the sample. Break conglomerations of mixture by hand. Take care to prevent loss of particles of mixture.

11.3. To calculate the specific gravity of the sample, substitute the final surface-dry mass for *A* in the denominator of Equations 2 or 3.

12. REPORT

12.1. Report the following information:

12.1.1. Specific gravity and density of the mixture to the third decimal place as: sp gr 25/25°C (77/77°F) or density at 25°C (77°F),

12.1.2. Type of mixture,

12.1.3. Size of sample,

12.1.4. Number of samples,

12.1.5. Type of container, and

12.1.6. Type of procedure.

13. PRECISION

13.1. Criteria for judging the acceptability of specific gravity test results obtained by this test method are given in the following table:

Test and Type Index	Standard Deviation (1S)	Acceptable Range of Two Results (D2S)
Test results obtained without use of Section 11[a]		
Single-operator precision	0.0040	0.011
Multilaboratory precision	0.0064	0.019
Test results obtained with use of Section 11 applicable for bowl determination only[b]		
Single-operator precision	0.0064	0.018
Multilaboratory precision	0.0193	0.055

[a] Basis of estimate: 3 replicates, 5 materials, 5 laboratories.

[b] Basis of estimate: 2 replicates, 7 materials, 20 laboratories.

13.2. The figures given in Column 2 are the standard deviations that have been found to be appropriate for the conditions of the test described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests. Multi-laboratory precision has not been verified for the 4500-mL or larger pycnometer.

13.3. The values in Column 3 are the acceptable range for two tests. When more than two results are being evaluated, the range given in Column 3 must be increased. Multiply the standard deviation(s) in Column 2 by the multiplier given in Table 1 of Practice ASTM C 670 for the number of actual tests.

Example for three tests: $0.020 \times 3.3 = 0.066$.

Additional guidance and background is given in Practice ASTM C 670.

Table 1—Influence of Temperature Corrections to a Measured Volume at 20°C of a Given Mass of Loose Paving Mixture, to Provide the Required Theoretical Maximum Specific Gravity at 25°C

Temperature °C	Volume Loose Mix at 20°C	Volume Correction for Temp Change	Corrected Volume at 20°C, Loose Mix	Mass of Loose Mix	Specific Gravity, Loose Mix
1	2	3	4 = 2 + 3	5	6 = $^{5}/_{4}$
31	492.77	0.2046	492.975	1251.3	2.5383
30[a]	492.77	0.1860	492.956	1251.3	2.5384
29[a]	492.77	0.1674	492.937	1251.3	2.5385
28[a]	492.77	0.1488	492.919	1251.3	2.5386
27[a]	492.77	0.1302	492.900	1251.3	2.5386
26[a]	492.77	0.1116	492.882	1251.3	2.5387
25[a]	492.77	0.0930	492.863	1251.3	2.5388
24[a]	492.77	0.0744	492.844	1251.3	2.5389
23[a]	492.77	0.0558	492.826	1251.3	2.5390
22[a]	492.77	0.0372	492.807	1251.3	2.5391
21[a]	492.77	0.0186	492.789	1251.3	2.5392
20	492.77	0.0000	492.772	1251.3	2.5393
19	492.77	–0.0186	492.751	1251.3	2.5394

[a] Range less than 0.0005.

Notes: Strictly speaking, the above table shows that the specific gravity for this particular mix, as measured at 20°C, just fails to meet the corrected theoretical maximum specific gravity at 25°C, 2.5388 versus 2.5393, that is, by 0.0005, and that a temperature correction would be required. If the measurement for volume had been made at 21°C, the table indicates that no temperature correction would have been necessary, because the measurement at 21°C would have satisfied the theoretical maximum specific gravity at 25°C, 2.5388 versus 2.5392, a difference of less than 0.0005.

APPENDIX

(Nonmandatory Information)

A1. THEORETICAL MAXIMUM SPECIFIC GRAVITY FOR A LOOSE-PAVING MIXTURE

A1.1. *Scope:*

A1.1.1. This Appendix Has Two Objectives:

A1.1.1.1. To indicate a method for correcting the theoretical maximum specific gravity to 25°C when measurements are made at temperatures other than 25°C.

A1.1.1.2. To indicate the range of temperature in °C above or below 25°C within which no temperature correction is required, because the measured theoretical maximum specific values are shown to be 0.0004 or less than the value for 25°C.

A1.2. *Indicated Values*:

A1.2.1. The following are indicated for the theoretical maximum specific gravity of a loose-paving mixture:

A1.2.1.1. Mass of loose-paving mixture = 1251.3 g.

A1.2.1.2. Volume of loose-paving mixture at 25°C = 492.77 mL.

A1.2.1.3. Asphalt content = 5.0 percent of total mix.

A1.2.1.4. Specific gravity of asphalt at 25°C = 1.029.

A1.2.1.5. ASTM bulk specific gravity of aggregate = 2.714.

A1.2.1.6. Cubical coefficient of expansion of asphalt at 20°C = 6.2×10^{-4} mL/mL/°C (Practice D 4311).

A1.2.1.7. Cubical coefficient of expansion of aggregate at 20°C = 2.2×10^{-5} mL/mL/°C.[2]

A1.3. *Basis of Calculation for One Gram of Loose-Paving Mixture at 20°C*:

A1.3.1. Mass of asphalt = 0.05 g.

A1.3.2. Volume of asphalt = 0.05/1.029 = 0.0486 mL.

A1.3.3. Mass of aggregate = 0.95 g.

A1.3.4. Volume of aggregate = 0.95/ 2.714 = 0.3500 mL.

A1.3.5. Volume of asphalt plus aggregate in one gram of loose-paving mixture at 20°C = 0.0486 + 0.3500 = 0.3986 mL.

A1.4. *Basis of Calculation for Volume Change of One Gram of Loose-Paving Mixture for1°C from 20°C:*

A1.4.1. Volume change for asphalt = $6.2 \times 10^{-4} \times 0.0486 = 0.3013 \times 10^{-4}$ mL = 3.0130×10^{-5} mL.

A1.4.2. Volume change for aggregate = $2.2 \times 10^{-5} \times 0.3500 = 0.77 \times 10^{-5}$ mL.

A1.4.3. Volume change for one gram of loose paving mixture for 1°C change in temperature from 20°C = $3.0130 \times 10^{-5} + 0.7700 \times 10^{-5} = 3.7830 \times 10^{-5}$ mL.

A1.5. *Volume Correction*:

A1.5.1. For a difference in water temperature of 1°C above or below 20°C, a correction to the volume of water displaced by one gram of loose-paving mixture can be made by the following equation:

$$\text{Correction} = \Delta T \times K_T \times V_T \ mL \qquad (5)$$

where:

ΔT = 1°C,

K_T = volume change for 1 g of loose paving mixture for 1°C change in temperature above or below 20°C = 3.7830×10^{-5} mL, and

V_T = volume of water for corresponding 1251.3 g mass of loose-paving mixture at test temperature of 20°C = 492.77 mL.

Substituting in equation gives:

Correction = $1 \times 3.7830 \times 10^{-5} \times 492.77$ mL = 0.01864 mL per gram at 20°C.

[1] Sargent Welch, 39745 Gauge-Vacuum, Mercury Prefilled (or equivalent).
[2] Krebs and Walker, *Highway Materials*, McGraw-Hill, Inc., 1971, p. 274.